York University
Faculty of Environmental Studies

ENVS 3520 3.0
GEOGRAPHIC INFORMATION SYSTEMS IN ENVIRONMENTAL STUDIES

Lab Exercise #2 - Static GPS Surveying and Positional Error Assessment:
(Due before Oct 8th, 2002 – 10% of Final Grade)

Problem Statement

Your task in this lab will be to assess the positional accuracy of static GPS survey records from a Garmin™ GPS 12XL receiver. Positional accuracy will be described using the following descriptive spatial statistics: mean-centre (a centroid), coordinate range (bounding rectangle), and standard distance (SD circle). Students will need to be familiar with these simple spatial statistics.

Deliverables

At the end of two (2) weeks, the student will produce a map displaying the feature point data collected with the Garmin™ GPS receivers using the York University Campus aerial photo as the background image. A short report that assesses the overall positional accuracy of the data collected and a brief explanation of the possible contributing factors to error should be included.

Background

The global positioning system is a satellite-based navigation system consisting of a network of 24 orbiting satellites that are eleven thousand nautical miles in space and in six different orbital paths. The satellites are constantly moving at a rate of 1.8 miles per second making two complete orbits around the Earth in less than 24 hours. The orbital paths of these satellites take them between roughly 60 degrees North and 60 degrees South latitudes. Satellite signals can be acquired anywhere on the Earth's surface, at any time and in all weather conditions.

So what information does a GPS satellite transmit? The GPS signal contains a 'pseudo-random code', ephemeris (pronounced*: ee-fem-er-is*) and almanac data. The pseudo-random code identifies which satellite is transmitting—in other words, an I.D. code. Satellites are generally referred to by their PRN (pseudo-random number), from 1 through 32, and this is the number displayed on a GPS receiver to indicate which satellite(s) is being received.

Ephemeris data is constantly transmitted by each satellite and contains important information such as status of the satellite (healthy or unhealthy), current date, and time. To determine your position, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received by the GPS receiver. The time differential allow for the calculation of distance between receiver and that particular satellite. If at least two more distance measurements are used, a triangulated position on the Earth's can be calculated. This is exactly what a GPS receiver does. With a minimum of three or more satellites, a GPS receiver can determine a coordinate position—what's called a 2D position fix. With four or more satellites, a GPS receiver can determine a 3D position which includes an Easting (x), Northing (y), and Elevation (z). By continuously updating position, a GPS receiver can also accurately provide speed and direction of travel (referred to as 'ground speed' and 'ground track').

GPS Positioning and Error

Everything has to be somewhere. So every object can potential have a reference of location associated to it. Global Positioning Systems (GPS) calculate absolute positioning coordinates in either geographic references (e.g., latitude and longitude) or in projected coordinate systems like a regional Universal Transverse Mercator (UTM).

All geographically referenced information is subject to positional error. Below is a summary list of factors affecting GPS accuracy:

1) Satellite Geometry: In simple terms, satellite geometry refers to where the satellites are located relative to each other (from the perspective of the GPS receiver). If a GPS receiver is locked onto four satellites and all four of these satellites are in the sky to the north and west of the receiver, satellite geometry is rather poor. Satellite geometry also becomes an issue when using a GPS receiver in a vehicle, near tall buildings, or in mountainous or canyon areas. As more and more of the sky is obstructed by buildings or terrain, it becomes increasingly difficult to determine a position.

2) Multipath: Simply put, multipath is the result of a radio signal being reflected off an object. With GPS, multipath occurs when the signal bounces off a building or terrain before reaching the GPS receiver's antenna. The signal takes longer to reach the receiver than if it traveled a direct path. This added time makes the GPS receiver think the satellite is farther away than it really is, which adds error to the overall position determination. When they occur, multipath errors typically add less than 3 meters of error to your overall position.

3) Atmospheric Effects: Propagation delay due to atmospheric effects that result in very small positional errors. Propagation delay is the 'slowing down' of the GPS signal as it passes through Earth's ionosphere and troposphere. In space, radio signals travel at the speed of light, but they are significantly slower once they enter the atmosphere.

Reducing Position Error and Improving Positional Accuracy

All geographically referenced information is subject to positional error. Expect a field GPS receiver to displays positional coordinates that are different from the “true coordinates” of a terrestrial object. A typical civilian GPS receiver's accuracy can be improved to 2-5 meters or better. Although there are several approaches to improving position accuracy, *differential correction* is common to most of them. Differential correction can remove most of the common sources of error in GPS positioning. In this technique, a second receiver (i.e., a base station located on a surveyed position) is used to compute corrections to the roaming or field GPS measurements. This base station receiver is then coupled to your GPS receiver data and relays positional corrections. In the absence of differential correction, we can manually calculate simple spatial to assess the general positional accuracy of our GPS measurements.

Further Readings:

Lo, C.P., Yeung, K.W., 2002 Concepts and Techniques of Geographic Information Systems. Prentice Hall, New Jersey. (pp.52-54; and, 313-314)

GPS Glossary of Terms: http://www.rbf.com/cgcc/glossary.htm

Lab Exercise Objectives:

This exercise has been designed to allow students an opportunity to engage in field activities to generate static point feature data, integrate point feature data into ArcGIS, assess the positional accuracy of GPS measurements and produce cartographic output in ArcGIS. A better appreciation of coordinate referencing systems and positional error will also be developed.

New Procedures: Using Garmin™ GPS 12XL, Waypoint Finder software, assessing positional error, simple spatial statistics, and using ArcMap Drawing Tools.

WEEK 1

You will be working with a partner to complete this week's portion of the lab exercise. Your lab demonstrator will provide a Garmin™ GPS 12XL unit and demonstrate how to calibrate and operate it. Waypoint (destination coordinates) will be assigned to you and your partner.

a) Learn the basics of operating the Garmin GPS 12XL

Before going out on the field and recording spatial data, you must become comfortable with the GPS unit by setting the proper position format and datum and remove previous track and waypoints. The use of the equipment will be demonstrated in the lab, however you can also refer to the summary sheet of functions, and the on-line user manual on the web address http://celia.mehaffey.com/dale/wgarmin.html. Furthermore, you should become familiar with the type of words and expressions required for this lab exercise. You will find a glossary at the back of this lab assignment.

	Turns the unit on and off and activates screen backlighting.
	Scrolls through the main data pages in sequence and returns display from a submenu page to a primary page.
	Captures a position and displays the mark position page.
	Displays GOTO page with the waypoint highlighted for GOTO operation. Pressing GOTO twice activates MOB.
	Confirms data entry and activates highlighted fields to allow data entry.
	Returns display to a previous page, or restores a data field's previous value.
	Selects alphanumerical characters and menu choices and moves the field highlight from field to field.
	Moves the selected character field and moves the field highlight from field to field.

Once outside follow the following procedure for start-up.

1. Global Erase Function

Erase all previous waypoint records, routes and track logs:

i. Ensure the unit is OFF.
ii. While holding down the MARK key, turn the unit ON.
iii. A warning message will appear with YES highlighted
iv. Press ENTER to confirm and erase all previous data and settings.

2. Set the proper position and datum format

i. Press the Page button until you arrive at the Main Menu page
ii. Select Setup Menu, then select Navigation
iii. Scroll until the Position Format is active and press Enter
iv. Scroll to set the format to **UTM/UPS** and then press Enter
v. Scroll to the Map Datum area and press Enter
vi. The Map Datum we will be using for this lab is **NAD 83** (North American Datum 1983)

Figure 1.0 – keypad on the GPS unit. This is your interface to manage menu selections and make quick operation commands.

b) Entering the first of two provided UTM Coordinate pair values

You and your partner will be assigned two pair values. Record here the letter coordinates.

Waypoint _____ E _____ , N _____

Waypoint _____ E _____ , N _____

You will be entering these coordinates into the GPS unit as waypoints. You will use the Compass Screen to find the location on campus. To enter the first of your two pair values, following these instructions:

i. Go to the main menu and select waypoint.

ii. Select New from the 'on page' menu located at the bottom of the screen. (Remember that you can use the up arrow key to reach the bottom of the screen.)

iii. Enter the new Waypoint name (e.g., A, B, C…) and the UTM values.

iv. Select done when you are finished.

v. Repeat for the second Waypoint location you will be finding.

Take the GPS unit out on campus and find your Waypoint coordinates!

***** YOU MAY BE CROSSING ROADS TO FIND YOUR COORDINATES! YOU WILL BE CONCENTRATING ON THE GPS UNIT BUT ALWAYS BE AWARE OF YOUR SUROUNDINGS! *****

c) Finding your assigned UTM coordinate Pair Values

The GPS unit provides several pages which you can access through the keypad. The first one you will come across is the Satellite Page. It shows you how many satellites your unit is receiving and the strength of reception. Ensure you are at least 40 meters from any large structures that may block reception satellites in your horizon (i.e., angles of possible reception). You should have at least SIX (6) satellite signals acquired before you begin.

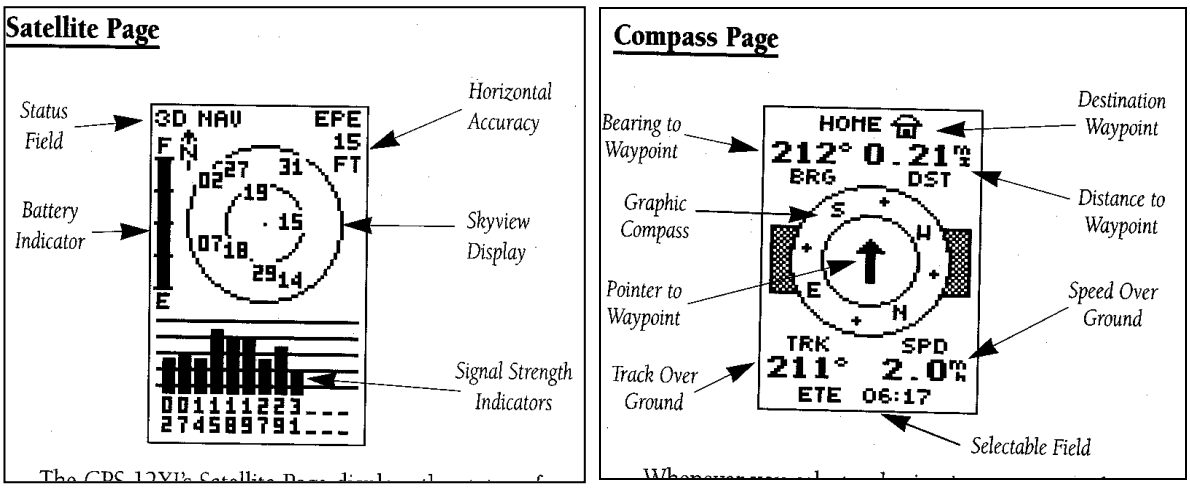

Figure 2.0 – The Satellite and Compass Page on the Garmin 12 XL unit.

The next important page is the Compass Page. This page will be the one to use when tracking to your waypoints. It will provide you with a bearing (from North), a directional arrow to your waypoint and an estimate of distance. The GPS unit will alert you once you are approximately 40 metres from your survey destination point. Keep moving until the distance to the waypoint is 0.00, or you have located the orange marker on the ground. Once there, you are ready to capture static waypoint samples.

Find your first Waypoint marker now.

d) Capturing Waypoints

Storing your present location is the usual way to record a waypoint. You will be capturing 25 waypoints, with at least 20 seconds between readings. To record a waypoint:

i. Hit the MARK key, the waypoint entry form will appear.
ii. A unique default name is assigned automatically – e.g. 001.
iii. No unique symbols or references are required for your waypoints.
iv. Wait for 20 seconds and repeat until you have 25 waypoint samples.
(note: the Compass Page has a clock for timing your intervals).

Once you have all your waypoints for your first destination, us the GOTO command to locate your second Waypoint sampling location. Repeat step d) and take 25 waypoints (with 20 second intervals). When finished, TURN OFF the GPS unit and return to the lab to complete the final step for this week's portion of the exercise.

e) Download the waypoints from the GPS unit

Turn on the unit. You will now download the waypoints from the GPS unit using the Waypoint+ software. This software is installed on the PCs in the Lumbers 318 lab.

i. Carefully connect the GPS unit to the serial port of a PC in the GIS Lab (watch the security cables!)
ii. Turn on the GPS Unit.
iii. Double click the Waypoint + icon to run the program.
iv. Ensure that the correct serial port is set by selecting GPS > Port > COMx (normally COM1 or COM2).
v. Set the datum to the appropriate value under /File/ Datum in the Waypoint+ software.
vi. Set the configuration to UTM, and meters under /File /Configuration in the Waypoint+ software.
vii. From the GPS menu in the Waypoint+ software select Download from GPS > All
viii. Downloading should now proceed – your GPS unit will give a message alert – press PAGE to see the message – it should read "Transfer has been completed"
ix. In the Waypoint+ software, select Waypoint/List waypoints/ to see what you've downloaded and confirm it's the correct data. You can also plot your waypoints for a quick visualization
x. From the /File/ menu select /Save.
xi. Make sure that you are saving this to your network drive, and Save As/ "Comma Delimited Text File"
xii. Exit Waypoint +.
xiii. Double check that the "Comma Delimited Text File" waypoint file has been saved in your network folder with a .txt file extension (e.g., sorrellwp.txt).

In order to do next week's work, you will need 50 waypoints for sampling one location. There is at least one other group that was assigned to the same two coordinates and have taken 25 readings. Next week you will be combining results by cutting and pasting records in MS-Excel.

END WEEK 1

Week 2 - Determine the Positional Accuracy of the GPS Sample Records

Data Sources:

Roads.shp – Desktop Mapping Technologies Inc. (DMTI) CanMap Series 2002
Ortho image – Triathlon Ltd., 1999.

f) Editing your text data files

i. Open MS-Excel and selected File/Open from the main menu. The File type you want is *.txt . Locate your waypoint data file from last weeks activities. Using the Text Import Wizard, open the file into Excel. Remember it is comma delimited text file.
ii. Now you need to edit all of the records. Remove the original waypoint records (rows) used to find the sampling locations (e.g., Waypoint A, B…). Also, remove the header (first) row that contains the GPS configuration settings.
iii. The first 25 records are from your first waypoint sampling location with the waypoint records 26-50 belonging to the second sampling location. Use the copy and paste function in excel to create 2 separate worksheets. Find another group in the lab that collected samples for your FIRST waypoint sampling area. Exchange MS-Excel files via a a floppy disk or e-mail attachment.
iv. Consolidate the 26-50 records from the second group into your excel worksheet. Now you should have 50 records in total.
v. Save the worksheet in your student network folder using the /FILE/SAVE AS/ command as a Dbase IV *.dbf file. Provide a copy of the file to your data collection partner.

[Individual lab work for submission].

g) Integrating and visualizing your waypoint data in ArcGIS

Copy all of the files in the ENVS3520/**Lab2**/ folder to your student network folder.
Double click on Lab2.mdx – this will open ArcMap

Add the aerial photo of York campus. To add the aerial photo into your map view use the add data toolbar button. Navigate back to the Course Lab 2 folder and into the /**Ortho** Folder. Select the 45621a.tif file to add to your project. Add "Pyramids" if prompted. The Pyramids option will create a lower resolution version of the aerial photo for faster display. For more information, use the ArcMap Help/Index and search under "Raster" and then scroll down "pyramids"

You will now import the waypoints into ArcMap using "Add Data".

If you are having problems open up Arc Catalogue ( ) and find the *.dbf file and drag it over to ArcMap's Table of Content (TOC). Once the table is in the TOC, right-click on it and scroll down to the Data XY…. Set the X to the Easting values and the Y to the Northing values. You should now see the scattering of point on the map. Zoom to the cluster of sampling points.

h) Assessing Positional Accuracy of the data

i. Open the attribute table of the point feature you just added to the data frame.
ii. Right click on the Easting column and scroll down to /Statistics on the pop-up menu. This is a fast way to get descriptive statistic for attribute information in ArcMap tables. Here the statistic required creating a centroid, bounding rectangle, and a standard distance circle/ellipsoid are presented. Refer to your Oct 1st , 2002 lecture notes for details on these simple spatial statistics. You will need to record statistic from both he Easting and Northing field in the table.
iii. Return to the map and create centroid using the point Drawing Tool located on the bottom of the ArcMap screen. Adjust the properties of the circle (e.g., colours and coordinates) so that it is appropriately presented and positioned.
iv. Now you will create a Standard Distance OVAL around the centroid. Assuming the positional error of your sample points are distributed normally, approximately 68% of the survey points should be contained within the diameter of the oval/circle. Click on the OVAL shape on the Drawing Tool and place it over the mean centroid. Double click on it and change the size. Easting and Northing values equate to width and height when configuring the positional properties of the oval. The colour setting should allow you to see all of the sampling points.
v. Finally, create a Bounding Rectangle. Use the rectangle Drawing Tool.

Now, visualize the results using the aerial orthophoto as the background image. Set the scale of the map to 1:1000 or a scale suitable to display the features appropriately. Activate the features and draw tool graphics and move to the layout view. Annotate the spatial statistics on the map with all of the appropriate cartographic elements to produce an informative map.

i) Lab Report

Your submission must address all of the items listed in the problem statement and in the description of the deliverables. Your understanding of the problem statement, the data you worked with, and the interpretation of the results, will account for the majority of your overall mark

Specifically, the lab report should include:

i. Discusses the positional accuracy assessment of the Garmin™ GPS 12XL unit. You should draw on the values calculated in the simple spatial statistics;

ii. Based on your experience, the pattern of dispersion of any positional error, discuss possible factors contributing to error in your waypoint samples;

iii. A table with all of the raw waypoint records with the calculated spatial statistics; and,

iv. A final map clearly displaying your sample waypoints, all graphic representation of the spatial statistics calculated, text annotations and all cartographic elements. Other screen captures may also be included in the report as the student deems necessary.

Please ensure your report format is consistent with the Lab Submission Guidelines distributed earlier in the term.

End.

Glossary

The GPS 12XL is a powerful navigation tool that can guide you anywhere in the world. To better understand its operation and capabilities, it may be helpful to review the basic terms and concepts briefly explained below.

Other navigation and GPS definitions used in the manual are defined in the appropriate reference sections of the manual.

Almanac Data

Satellite constellation information (including location and health of satellites) that is transmitted to your receiver from every GPS satellite. Almanac data must be acquired before GPS navigation can begin.

Bearing (BRG)

The compass direction from your position to a destination.

Course Made Good (CMG)

The bearing from the "active from" position (your starting point) to your present position.

Crosstrack Error (XTK)

The distance you are off a desired course in either direction.

Desired Track (DTK)

The compass course between the "from" and "to" waypoints.

Differential GPS (DGPS)

An extension of the GPS system that uses land-based radio beacons to transmit position corrections to GPS receivers.

Estimated Time of Arrival (ETA)

The time of day of your arrival at a destination.

Estimated Time Enroute (ETE)

The time left to your destination at your present speed.

INTRODUCTION

Glossary

Grid

Coordinate system that projects the earth on a flat surface, using square zones for position measurements. UTM/UPS and Maidenhead formats are grid systems.

Ground Speed (SPD)

The velocity you are traveling relative to a ground position.

Latitude

The north/south measurement of position perpendicular to the earth's polar axis.

Longitude

An east/west measurement of position in relation to the Prime Meridian, an imaginary circle that passes through the north and south poles.

Navigation

The process of traveling from one place to another and knowing where you are in relation to your desired course.

Position

An exact, unique location based on a geographic coordinate system.

Track (TRK)

The direction of movement relative to a ground position.

Universal Transverse Mercator (UTM)

A grid coordinate system that projects global sections onto a flat surface to measure position in specific zones.

Velocity Made Good (VMG)

The speed you are traveling in the direction of the destination.

Waypoint

A specific location saved in the receiver's memory.